EXOSKELETON

CROSS-REFERENCE TO RELATED PATENT DOCUMENTS

[0001] This document claims the benefit of priority, under 35 U.S.C. Section 119(e), to Rosen, U.S. Provisional Patent Application Ser. No. 60/743,934, entitled "EXOSKELETON FOR PHYSICAL THERAPY," filed on Mar. 29, 2006 (Attorney Docket No. 2082.009PRV), and is incorporated herein by reference.

GOVERNMENT RIGHTS

[0002] This invention was made with Government support under Contract or Grant No. IIS0208468 awarded by National Science Foundation. The Government has certain rights in this invention.

TECHNICAL FIELD

[0003] This document pertains generally to robotics, and more particularly, but not by way of limitation, to an exoskeleton.

BACKGROUND

[0004] Previous attempts to build a powered exoskeleton have been inadequate for various reasons. In some cases, the processor and control algorithms were too slow to make the structure move naturally with the user. In others, the power supplies and actuators have been cumbersome and sluggish.

OVERVIEW

[0005] The present systems and methods relate to an exoskeleton, or a wearable robot having joints and links corresponding to those of the human body. The system and method can be used in rehabilitation medicine, virtual reality simulation, and teleoperation, and for the benefit of both disabled and healthy populations.

[0006] The present system includes an anthropomorphic, seven degree-of-freedom, powered upper body exoskeleton. One example includes proximal placement of drive motors and distal placement of cable-pulley reductions, thus yielding low inertia, high-stiffness links, and back-drivable transmissions with zero backlash. One example enables full glenohumeral, elbow, and wrist joint functionality.

[0007] The human-machine interface is established at the neural level based on a Hill-based muscle model (myoprocessor) that enables intuitive interaction between the operator and the wearable robot. Some potential applications of the exoskeleton include an assistive (orthotic) device for human power amplifications, a therapeutic and diagnostics device for physiotherapy, a haptic device for use in virtual reality simulation, and a master device for teleoperation.

[0008] The exoskeleton of the present subject matter includes an external structural mechanism with joints and links corresponding to those of the human body. When used as an assistive device, the human wears the exoskeleton, and its actuators generate torques applied on the human joints. When used as a human power amplifier, the human provides control signals for the exoskeleton while the exoskeleton actuators provide some of the power necessary for task performance. The human becomes part of the system and applies a scaled-down force in comparison with the load carried by the exoskeleton. When used as a master device in a teleoperation system, the operator controls a secondary, possibly remote, robotic arm (slave). In a bilateral mode, the forces applied on the remote robotic arm by the environment are reflected back to the master and applied to the operator's arm by the exoskeleton structure and actuators. In this configuration, the operator feels the interaction of the robotic arm tool-tip with the environment. When used as a haptic device, the present subject matter enables human interaction with virtual objects simulated in virtual reality. As a result, virtual objects can be touched by the operator. The exoskeleton structure and its actuators provide force feedback, emulating the real object including its mechanical and textural properties. The exoskeleton, in that sense, simulates an external environment and adds the sense of touch (haptics) to the graphical virtual environment. Several mechanisms including arms, hands, legs and other haptic devices can be used.

[0009] This overview is intended to provide an overview of the present subject matter. It is not intended to provide an exclusive or exhaustive explanation. The detailed description is included to provide further information about the present subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In the drawings, which are not necessarily drawn to scale, like numerals may describe substantially similar components in different views. Like numerals having different letter suffixes may represent different instances of substantially similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0011] FIG. **1** illustrates a block diagram of one example of the present subject matter.

[0012] FIG. **2** illustrates angular variations between elbow flexion-extension and pronosupination axes resulting in different elbow flexion kinematics.

[0013] FIG. **3** illustrates joint axes for a human.

[0014] FIGS. **4**A, **4**B and **4**C illustrate various joint configurations.

[0015] FIG. **4**D illustrates an exoskeleton.

[0016] FIG. **5** illustrates a model of exoskeleton axes in relation to a human arm.

[0017] FIG. **6** illustrates some exoskeleton configurations that achieve rotation about the long axis of a limb segment.

[0018] FIG. **7** illustrates mechanical singularities.

[0019] FIG. **8** illustrates a two stage reduction drive.

[0020] FIG. **9** illustrates cable routing.

[0021] FIG. **10** illustrates a system block diagram and feedback control loops.

[0022] FIG. **11** illustrates a low level block diagram of a Hill-based muscle model.

[0023] FIG. **12** includes a block diagram of an algorithm for evaluating neural activation level based on sEMG.

[0024] FIG. **13**A illustrates exoskeleton operation in virtual reality with a user wearing a head mounted display.